# CHAPTER 12.—EXPLOSION HAZARDS OF COAL DUST IN THE PRESENCE OF METHANE

By Kenneth L. Cashdollar[1] and Michael J. Sapko[2]

## *In This Chapter*

- ✓ Methane ignition as initiation source for much larger secondary coal dust explosions
- ✓ Rock dusting requirements to prevent coal dust explosions
- ✓ Dangers of hybrid mixtures of methane and coal dust

Although methane explosions are dangerous, those that involve coal dust are even more so. If exploding methane disperses and ignites the coal dust that has accumulated on the mine ribs and floor, the burning coal dust immeasurably increases the strength of the explosion. Such methane-dust explosions are prevented by inerting the coal dust in a way that prevents the exploding methane from igniting it. This chapter discusses the dust hazard and how it is prevented in U.S. coal mines.

## METHANE IGNITION AS INITIATION SOURCE FOR MUCH LARGER SECONDARY COAL DUST EXPLOSIONS

The typical scenario for coal mine explosions starts with the ignition of a flammable methane-air atmosphere near the face. The turbulent winds from the primary methane explosion then disperse the coal dust. If there is insufficient rock dust (usually limestone), a secondary coal dust explosion then propagates throughout large sections of the mine. These scenarios have been studied extensively at the Bruceton Experimental Mine (BEM) and the Lake Lynn Experimental Mine (LLEM) of the NIOSH Pittsburgh Research Laboratory.

The minimum quantity of methane required to initiate a coal dust explosion was studied in 1930 in the BEM [Rice et al. 1933; Nagy 1981] and then later in the LLEM, whose cross-sectional area (130 $ft^2$) is over twice that of the BEM [Sapko et al. 1987a]. Studies conducted in the BEM closely simulated conditions that existed in operating mines in the early 20th century. The later tests in the 20-ft-wide entries of the LLEM simulated the geometries of modern mines with advanced roof support technology.

The data from the BEM tests show that 13 $ft^3$ was the minimum quantity of methane at the face that, when ignited, would disperse and ignite coal dust. In the BEM, this amount of methane was mixed with air to form a total flammable volume of about 140 $ft^3$ of a 9% methane-in-air mixture. In the wider entries of the LLEM, about 37 $ft^3$ of methane was required to disperse pure coal dust and start a self-sustained coal dust explosion. This amount of methane was mixed with

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[1]Research physicist.
[2]Research physical scientist.
Pittsburgh Research Laboratory, National Institute for Occupational Safety and Health, Pittsburgh, PA.

air in a 6-ft by 9-ft by 6.5-ft high plastic containment zone to form a total flammable volume of about 350 $ft^3$ of a 10% methane-air mixture. Based on the 54-$ft^2$ cross-section of the BEM and the 130-$ft^2$ cross-section of the LLEM, both of these methane-air volumes would correspond to a linear distance of about 2.5 ft from the face.

Although the entire cross-sections are used for this comparison, the actual methane-air zones in both the BEM and LLEM only partially filled the cross-sections. If obstacles were added to the methane zones to create turbulence, the methane explosions could be even more effective at dispersing coal dust. It should also be noted that these experimental mine tests were somewhat idealized conditions because there was no rock dust mixed with the coal dust, as would normally be the case under real mining conditions. In addition, the dust was all on shelves near the roof. This arrangement provided the easiest conditions for initiating a dust explosion. In a mine with rock dust added to the coal dust and with most of the dust deposited on the floor, more methane would be required to disperse and ignite the dust mixture.

## ROCK DUSTING REQUIREMENTS TO PREVENT COAL DUST EXPLOSIONS

**The primary method of preventing coal dust explosions in underground mines is to add sufficient amounts of an incombustible rock dust (usually limestone) to the coal dust. Then, even if the coal and rock dust mixture is dispersed into the air by a methane explosion, a secondary dust explosion will not occur. The rock dust acts as a heat sink to cool the explosion temperature below the temperature needed for continued propagation.**

30 CFR[3] 75.402 to 75.404 requires rock dusting in all underground bituminous coal mines:

> All underground areas of a coal mine, except those areas in which the dust is too wet or too high in incombustible content to propagate an explosion, shall be rock dusted to within 40 feet of all working faces…Where rock dust is required to be applied, it shall be distributed upon the top, floor, and sides of all underground areas of a coal mine and maintained in such quantities that the incombustible content of the combined coal dust, rock dust, and other dust shall be not less than 65 per centum, but the incombustible content in the return aircourses shall be no less than 80 per centum.

The higher incombustible content required for returns is based on the finer size of coal dust found in returns. The regulations further state that—

> Where methane is present in any ventilating current, the per centum of incombustible content of such combined dusts shall be increased 1.0 and 0.4 per centum for each 0.1 per centum of methane where 65 and 80 per centum, respectively, of incombustibles are required.

[3]*Code of Federal Regulations*. See CFR in references.

The above paragraph means that the incombustible content of the dust in intakes must be increased from 65% to 75% if the ventilating air contains 1% methane. Similarly, the incombustible content of the dust in returns must be increased from 80% to 84% if the ventilating air contains 1% methane. The incombustible content of the dust mixture includes the rock dust, the ash content of the coal dust, and the moisture content. These regulations are based on research conducted at the BEM [Rice and Greenwald 1929; Rice et al. 1933; Nagy 1981].

There is an additional hazard when the rock dust is not well mixed with the coal dust. If there is a thin layer of float coal dust (dust that has been carried and deposited by the ventilation air) on top of a thick layer of properly rock-dusted floor dust, a weak methane explosion may preferentially lift the top layer of coal dust. The explosion can then continue to propagate through and beyond the length of the float coal dust deposit. This has been demonstrated in full-scale experimental mine tests [Nagy et al. 1965; Sapko et al. 1987b].

## DANGERS OF HYBRID MIXTURES OF METHANE AND COAL DUST

Chapter 1 discusses the lower flammable limit (LFL)[4] for methane and some of the ways that methane can be ignited. With only methane present, the LFL is 5% methane in air. However, when coal dust is added to the methane-air mixture, the LFL of the mixture is reduced. This can occur at the mining face, where methane is being liberated and coal dust is being generated.

The Le Chatelier linear mixing law[5] for the LFL of gases is also roughly applicable to a hybrid mixture of methane gas and coal dust. Figure 12–1 shows flammable limit data from BEM tests [Cashdollar et al. 1987] for coal dust dispersed with methane. Additional laboratory data [Cashdollar 1996; Cashdollar et al. 1987] confirm the roughly linear relationship for various coal dusts mixed with methane. In the example in Figure 12–1, the LFL of methane alone is 5% and the LFL of the coal dust by itself is 0.10 oz/ft$^3$. It should be noted that this is only an example and that the LFL of various coal dusts will vary with the particle size and volatility. The area below and to the left of the dashed line in the figure represents nonflammable mixtures. The area above and to the right of the dashed line

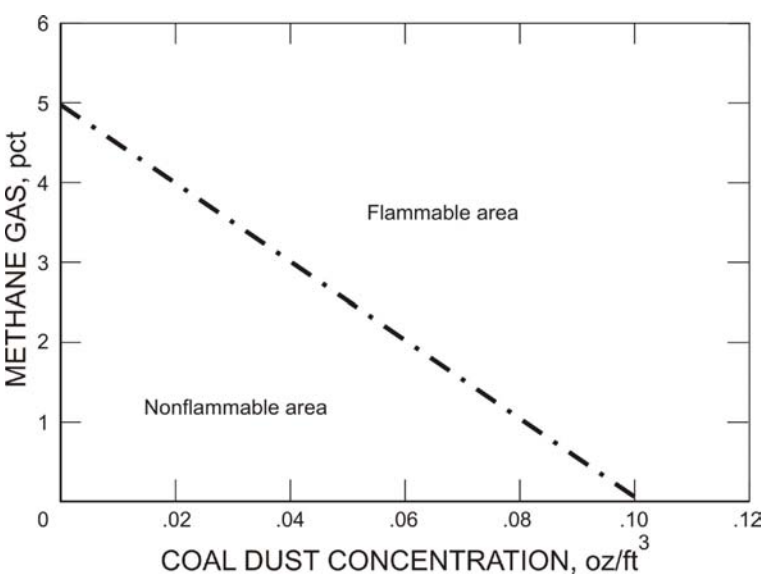


**Figure 12–1.—Flammable limits for mixtures of methane and coal dust.**

[4]Also called the lower explosive limit (LEL).
[5]See the section entitled “Addition of other flammable gases to air” in Chapter 1.

represents flammable mixtures. For example, if 3.5% methane is present, then any coal dust concentrations above 0.03 $oz/ft^3$ are flammable when mixed with the methane. If 2% methane is present, then any coal dust concentrations above 0.06 $oz/ft^3$ are flammable. This means that, if sufficient coal dust is present, an ignition can still occur at the mine face even if the methane concentration is below the 5% LFL.

## REFERENCES

Cashdollar KL [1996]. Coal dust explosibility. J Loss Prev Process Ind *9*(1):65–76.

Cashdollar KL, Sapko MJ, Weiss ES, Hertzberg M [1987]. Laboratory and mine dust explosion research at the Bureau of Mines. In: Industrial dust explosions. ASTM Special Technical Publication (STP) 958. West Conshohocken, PA: American Society for Testing and Materials, pp. 107–123.

CFR. Code of federal regulations. Washington DC: U.S. Government Printing Office, Office of the Federal Register.

Nagy J [1981]. The explosion hazard in mining. Arlington, VA: U.S. Department of Labor, Mine Safety and Health Administration, Informational Report (IR) 1119.

Nagy J, Mitchell DW, Kawenski EM [1965]. Float coal hazard in mines: a progress report. Washington, DC: U.S. Department of the Interior, Bureau of Mines, RI 6581.

Rice GS, Greenwald HP [1929]. Coal dust explosibility factors indicated by experimental mine investigations, 1911 to 1929. Washington, DC: U.S. Department of the Interior, Bureau of Mines, Technical Paper (TP) 464.

Rice GS, Greenwald HP, Howarth HC [1933]. Explosion tests of Pittsburgh coal dust in the experimental mine, 1925 to 1932 inclusive. Washington, DC: U.S. Department of the Interior, Bureau of Mines, Bulletin 369.

Sapko MJ, Hertzberg M, Watson RW, Cashdollar KL [1987a]. Dust explosion size scaling. In: Proceedings of the Shenyang International Symposium on Dust Explosions (Shenyang, China, September 14–16, 1987).

Sapko MJ, Weiss ES, Watson RW [1987b]. Explosibility of float coal dust distributed over a coal-rock dust substratum. In: Proceedings of the 22nd International Conference of Safety in Mines Research Institutes (Beijing, China, November 2–6, 1987).